Optimal positive-end expiratory pressure weaning in acute respiratory distress syndrome patients

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Purpose of review
Positive-end expiratory pressure (PEEP) is a tool in managing acute respiratory distress syndrome (ARDS). In this review, we discuss the various approaches to weaning PEEP after the acute phase of ARDS.

Recent findings
There is a paucity of research specifically looking at the differences between PEEP weaning protocols. Data in some populations though, particularly those with elevated BMI, suggest that a physiologic approach to PEEP weaning may be helpful. Use of various tools to optimize PEEP prior to and during spontaneous breathing trials (SBTs) may allow for improved alveolar recruitment and respiratory outcomes.

Summary
Although further prospective studies are warranted, we should consider using a physiologic approach to PEEP weaning in ARDS rather than a one size fits all model, which is currently the standard used in many clinical trials and throughout many ICUs.

Keywords
acute respiratory distress syndrome, mechanical ventilation, positive-end expiratory pressure, weaning

INTRODUCTION

For decades, the critical care community has recognized positive-end expiratory pressure (PEEP) as a key component in managing acute respiratory distress syndrome (ARDS) [1]. It is a tool to prevent alveolar collapse at end expiration, a process which poses the risks of atelectrauma and subsequent biotrauma [2,3]. Current best practices in the treatment of ARDS emphasize lung protective ventilation, a set of strategies that includes the use of PEEP, to reduce the ventilators' role in iatrogenic injury to the lungs [4]. Just as efforts have been made to better understand the ideal approach to PEEP titration during the acute phases of ARDS, it is also essential that we understand PEEP weaning as it applies to ventilator liberation [5–8].

As clinicians often underestimate patients' readiness to liberate from mechanical ventilation, protocols can help facilitate this weaning process. Current guidelines support performing daily trials of weaning sedation and ventilator settings, more commonly referred to as spontaneous awakening trials (SATs) and spontaneous breathing trials (SBTs), which have been shown to reduce duration of mechanical ventilation and ICU length of stay [9,10]. Although clinicians generally agree that in order to qualify for weaning, there need to be improvements in oxygenation, the underlying disease process, and overall degree of critical illness, the degree of improvement remains under debate. Identifying patients who are ready for this transition to lower levels of PEEP, let alone spontaneous assisted breathing remains an area of active investigation [11▪]. Nevertheless, these early studies demonstrating the benefit of SAT/SBTs, unanimously required that in order for patients to qualify for a SBT, their PEEP had to already be equal to or less than 5 cmH_2O. They did not clearly address the question of how to wean PEEP from the higher levels usually seen in the acute phase of ARDS down to the lower level that was mandated to proceed with SBT.

In this review, we seek to describe the specific situations where evidence-based approaches to PEEP weaning prior to and during SBT exist, and where the research is lacking, to describe our institution's approach to it.

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Curr Opin Crit Care 2024, 30:85–88
DOI:10.1097/MCC.0000000000001122

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KEY POINTS

- There are little data and no large studies specifically studying optimal PEEP weaning strategies.
- Although multiple large studies have included PEEP weaning recommendations, it is difficult to separate the impact of these strategies from the larger protocol in terms of understanding an 'optimal' approach.
- General consensus is that PEEP can slowly be decreased as the FiO_2 improves and patients are clinically improving using PEEP-FiO_2 tables or empirically in order to prepare patients for undergoing SBT and extubation.
- A 'physiological' approach has also been suggested with titration of PEEP via esophageal manometry, electrical impedance tomography or other system with PEEP maintained at these individualized levels without weaning until patients are ready for SBT and extubation.
- Patients with obesity in particular may benefit from this physiological approach to PEEP weaning with compelling, but preliminary data suggesting that this population may benefit from extubation directly off higher levels of PEEP to NIV.

WHAT WE KNOW

As in the studies addressed above, the weaning protocols utilized in various landmark studies of patients in ARDS, similarly mandated relatively low PEEP settings (i.e. 5–10 cmH_2O) before consideration of an SAT/SBT. Although little guidance was offered on how to reach that low level of expiratory support or on deciding when this low level of support may not be appropriate, we can look more closely at their overall weaning protocols to extrapolate potential approaches to this aspect of PEEP weaning.

Many of these studies utilized PEEP/FiO_2 tables to ensure patients were always maintained on the lowest tolerated PEEP and FiO_2 settings to still maintain adequate oxygenation [4,5,12]. Using either the high or low PEEP ARDSnet tables, the clinician would be guided to slowly decrease PEEP as the patients' FiO_2 requirements improved, for example, dropping the PEEP to 5–8 cmH_2O when the FiO_2 requirements had dropped to 0.40 when using the low PEEP table. The EPVent study looking at PEEP titration with use of esophageal balloon measurements, added that clinicians should not decrease the PEEP by more than 2 cmH_2O every 2 h to avoid rapid lung derecruitment [12]. To date, the majority of these ARDS studies have utilized PEEP weaning protocols that rely on improvements in oxygenation, and therefore presumably lung injury, to dictate a slow decremental PEEP titration. Near uniformly, once these improvements occurred and other prespecified criteria were met, patients were placed on an SBT. At a minimum, these criteria often included FiO_2 0.4–0.5 or less, and adequate blood pressures on low dose or no vasopressors, in addition to the low PEEP of 5–10 cmH_2O. The preferred SBT method used in the majority of these studies involved placing the patient on a pressure support mode of ventilation with a PEEP of 5 cmH_2O, with low FiO_2 and inspiratory support settings. Other studies have also shown the safety of performing SBTs with a T-piece [4,5,13▪].

It remains difficult to tease out any impact of the PEEP weaning strategies from these clinical research protocols as their purpose was not specifically targeted to investigation of the weaning phase. Additional guidance is needed as to the appropriate time to initiate PEEP weaning relative to the acute phase of ARDS. Future efforts should focus on exploring the validity of these cutoffs and whether there are other criteria that would serve as better markers for the appropriateness of transitioning to spontaneous breathing [4,5,12].

With no randomized controlled trials specifically looking at timing of or different approaches to PEEP weaning, significant variability persists with regards to expert clinician opinion [14]. To combat this lack of clear-cut guidance, recent ARDS research efforts have sought to define a precision-based approach to ventilator management. Researchers have identified subgroups of patients who might benefit from unique approaches to PEEP management and weaning. Specifically, patients with high BMI and ARDS have altered respiratory mechanics that benefit from higher PEEP strategies. To elaborate, these patients often have a reduced expiratory reserve volume (ERV) and functional residual capacity (FRC) related to displacement of their diaphragm. The effects of central adiposity ultimately increase the pleural pressure, making the transpulmonary pressure more negative at end expiration, predisposing the alveoli to atelectasis [15,16]. The significance of these findings is becoming more and more relevant for intensivists as the proportion of critically ill patients with obesity is on the rise, and we know that these patients are more likely to develop ARDS compared with patients with normal BMI [17,18].

To address these altered mechanics, patients with obesity and ARDS require higher airway pressures to recruit lung units relative to patients with ARDS but normal BMI [19,20▪]. Studies comparing different PEEP titration strategies in patients with a BMI greater than 35 kg/m^2, have shown that higher PEEP strategies result in reduced atelectasis, improved lung elastance, and better oxygenation [21].

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When attempting to liberate patients with high BMI from the ventilator then, experts such as Kacmarek *et al.* [22] recommend SBTs that apply optimum PEEP to ensure a positive end-expiratory transpulmonary pressure and thereby improve the patients' work of breathing. They argue against standardized PEEP of 5 cmH_2O for all patients undergoing SBT. They posit that too many patients with ARDS and obesity undergo unnecessary tracheotomy because of ineffective PEEP management during ventilator weaning and as such favor the use of recruitment maneuvers with decremental PEEP titration, esophageal balloons, or electrical impedance tomography to optimize PEEP prior to and during SBTs. Although there are no randomized controlled trials that look at this specifically, Obi *et al.* did show that PEEP titration, in this patient population, via use of esophageal balloon measurements as a surrogate for transpulmonary pressures resulted in faster liberation times compared with patients whose PEEP was titrated to optimize static compliance [23]. PEEP levels in the study increased significantly from a mean of 14 cmH_2O to a mean of 27 cmH_2O with the use of esophageal balloon titration. Fair counter-arguments to this higher PEEP approach include the risk of under-recognizing cardiac dysfunction as well as the risk of overestimating the degree of ARDS improvement. Our knowledge though that nearly all of these patients would benefit from extubation to noninvasive ventilation (NIV) with an expiratory positive airway pressure (EPAP) of at least 10 cmH_2O, to prevent lung decruitment and reintubation, could help mediate these potential risks [16,24].

Others favor applying this precision and physiologic-based approach to ARDS patients more broadly. They propose that PEEP is to be maintained at 'physiological' (i.e. often higher) levels without decreasing until patients are otherwise deemed ready for extubation. With this, PEEP would be left unchanged until patients are awake and spontaneously breathing. Patients would then undergo either rapid decrease in PEEP as part of the SBT, or the SBT would be performed while on higher levels of PEEP. The proposed benefit is preventing atelectasis by providing patients the necessary PEEP until they are able to breathe on their own without ventilator support.

Data to support this strategy remains limited; however, its use in high-risk cardiac surgery patients did reduce the incidence of severe pulmonary complications [25]. A study using electrical impedance tomography (EIT) to titrate intraoperative PEEP compared with standard approaches showed similar feasibility and potential for benefit. In the intervention cohort with EIT-guided PEEP, patients were extubated directly from a higher PEEP level, and this group demonstrated a decrease in atelectasis and improved aeration as seen by CT scan after extubation [26]. A study in patients with severe ARDS used high PEEP strategies to maintain lung recruitment, and extubated patients directly from 10 cmH_2O to NIV without significant clinical complications, though further randomized prospective trials are warranted [27].

With limited studies thus far, we should be cautious about generalizing these recent findings to other difficult to wean populations in ARDS. Nevertheless, extrapolating these findings support more broadly a physiologic-based approach to PEEP titration and weaning. Patients with neuromuscular disease are at increased risk of weaning failure and requiring tracheotomy, yet there is a paucity of literature specifically addressing weaning protocols, let alone PEEP weaning protocols, in these patients [28]. Although robust prospective studies would be necessary, for now, we can infer that a similar physiologic-based approach to PEEP weaning could be helpful in these patients or in other difficult-to-wean patients, such as those with cardiac dysfunction.

HOW WE DO IT

Although we agree with the need for ongoing investigation into the outcomes of a physiologic approach to PEEP weaning, our institution currently utilizes a more standardized approach to PEEP weaning in ARDS. For many patients, but particularly those with higher BMIs, we rely heavily on the use of esophageal balloon measurements as a surrogate for transpulmonary pressures. Using these measurements, we often target an end-expiratory trans-pulmonary pressure between −2 and 2 cmH_2O, while also using the end inspiratory trans pulmonary pressure as a safety marker to avoid alveolar over-distension. As patients with ARDS start to show signs of improving lung injury, as indicated by improvements in FiO_2 requirement, static compliance, and overall degree of critical illness, we slowly decrease their PEEP empirically while assessing for any worsening clinical status as it is lowered. Although physicians are often involved in these conversations, a large portion of PEEP weaning also occurs at the bedside through the expertise of our respiratory therapists. Once patients maintain adequate oxygenation and ventilation with PEEP less than 10 cmH_2O and FiO_2 less than 0.6, from a respiratory perspective, we consider them ready for a SAT/SBT. In an effort to minimize sedation and mechanical ventilation times, our institution has implemented nursing and respiratory therapy-driven protocols for SATs/SBTs. Our SBT protocol utilizes pressure support mode and places all patients on an inspiratory support of 5 cmH_2O and a PEEP of

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0 cmH_2O for at least 30−min. In many patients with severe obesity, we are increasingly using higher PEEP for SBT (8–15 cmH_2O depending on the patient) if failing traditional SBT with low PEEP, and then extubating these patients to BiPAP. There is not, however, a standardized approach, and improved protocols are needed.

CONCLUSION

As patients with ARDS transition out of the acute phase of their lung injury, there is scarce guidance for clinicians on how to down titrate their PEEP. Little is known regarding the rate at which this should be weaned or even to what level of PEEP this weaning should stop at before proceeding to a trial of spontaneous breathing. There is developing data to support a physiologic-based approach to PEEP weaning, particularly in certain patient populations such as those with elevated BMI. We are optimistic about future efforts to apply these same principles to other populations with ARDS in an effort to provide precision-based care to our critically ill patients.

Acknowledgements

None.

Financial support and sponsorship

None.

Conflicts of interest

E.B.K. has received lecturing fees for educational talks from Hamilton Medical Inc unrelated to this submission.

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- ■ of special interest
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